

# NASA TECH BRIEF

*Ames Research Center*



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## Mathematical Model for Predicting Human Vertebral Fracture

The causes of spinal fracture are of great concern in aerospace programs and every effort is made to minimize risk. However, in spite of a wide range of safety features, pilots ejected from aircraft or those involved in crash landings persistently suffer spinal fractures; of even greater concern is that designs of aircraft and space vehicles are under consideration in which impact acceleration of the human body along its spinal axis appears to be unavoidable. Moreover, impact acceleration of the human body may be a regular occurrence with delta platforms and lifting bodies which touch down at a high angle of attack, or an infrequent occurrence in vertical take-off aircrafts and lunar landing vehicles.

The determination of whether a spinal fracture will occur as a result of the impact incurred in a flight operation is dependent on the careful evaluation of several groups of factors, each consisting of a large number of concatenated physical parameters. One group relates to the external forces brought to bear on the area of application, including the initial conditions prior to impact. A second group relates to the transmission of impact forces within the body and the effect on the mass, viscosity, and elasticity of the component parts. A third group relates to the factors governing the fracture itself, i.e., the dynamic strength of each element of the spine; if each element is stronger than the applied force, no fracture will occur, but if the applied force is extraordinary, one fracture cannot attenuate it sufficiently to prevent the occurrence of other fractures.

A mathematical model has been constructed to predict the dynamic response of tapered, curved beam columns inasmuch as the human spine closely resembles this form. The model takes into consideration the effects of impact force, mass distribution, and material properties. In the derivation of the differential equations, the spine is assumed to be a homogeneous, isotropic, linearly elastic, tapered-beam column having an initial curvature in a plane; the mass center and the centroid of each cross section is not assumed to be coincident. Force is applied to one end of the beam column and a concentrated mass is assumed pinned to the opposite end. Deflections resulting from shear, axial compression, and bending are considered. The axial, rotary, and transverse inertia of each element is incorporated, but gravity effects are neglected. When motion is restricted to the plane of initial curvature, and the beam is initially unstrained, application of Hamilton's principle yields a set of coupled, nonlinear, partial differential equations which can be solved by numerical techniques.

Solutions were verified by dynamic tests on a curved, tapered, elastic polyethylene beam. Parameterization of the model was accomplished by dynamic and static flex tests on excised human vertebral segments from the thorocolumbar spine; the segments consisted of 8 to 10 vertebral bodies from the anatomical level between T7 and L3, and were tested under conditions in which the predominant source of deformation was attributable to bending stresses rather than to shear stresses.

(continued overleaf)

**Notes:**

1. The following documentation may be obtained from:

National Technical Information Service  
Springfield, Virginia 22151  
Single document price \$3.00  
(or microfiche \$0.95)

**Reference:**

NASA CR-114452, (N72-22077), Investigation of Vertebral Injury Sustained During Aircrew Ejection.

2. No additional documentation is available. Specific

questions, however, may be directed to:

Technology Utilization Officer  
Ames Research Center  
Moffett Field, California 94035  
Reference: B73-10033

**Patent status:**

NASA has decided not to apply for a patent.

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